Carbon Storage Using Organic Soil Amendments on California's Coastal Rangelands

Carbon dioxide (CO_2) is the primary greenhouse gas responsible for global climate change. Land use practices that conserve or increase terrestrial carbon storage as a way to mitigate carbon emissions are currently under investigation by the climate change research community. These practices may also enhance soil fertility and plant productivity, and reduce evaporative water losses from rangelands, thereby protecting agricultural viability consistent with Coastal Act policies. This fact sheet examines increasing carbon storage using organic soil amendments as part of rangeland operations, and discusses the potential opportunities for, and benefits of, the use of this practice.

Organic Soil Amendments

One method of increasing terrestrial carbon storage involves the application of organic amendments to rangeland soils in California.

Figure 1: Some materials currently used as organic amendments applied to California rangelands

When applied to rangeland soils, organic amendments are found to have multiple environmental benefits. Because organic amendments are often the waste products of agricultural practices, their reuse removes these materials from the waste stream, thereby reducing the burden to landfills. Application of organic amendments can also reduce greenhouse gases by augmenting plant growth and altering the soil processes that return carbon to the atmosphere.

Carbon Cycle

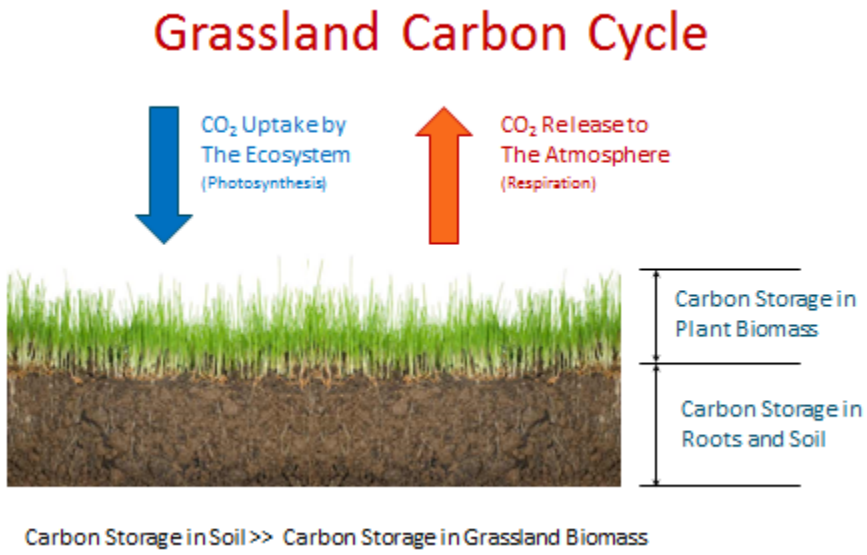


Figure 2: The grassland carbon cycle

Organic carbon, a primary constituent of all living things, is in a process of continual exchange between the land surface and the atmosphere. Carbon dioxide is taken up by plants through photosynthesis, and is stored in living plant tissues, both above and below ground. As plant tissues die and undergo decay, they are consumed and broken down by soil fauna and microbes (primarily bacteria and fungi). Through this process, carbon becomes churned into the soil matrix and bound to mineral particles. Individual organic carbon molecules remain in the soil on timescales ranging from days to centuries, as soil microbes progressively degrade, consume, resynthesize, and respire plant residues. Globally, approximately three times more carbon is stored in soil than in plant biomass. In grasslands, that ratio can be much higher.

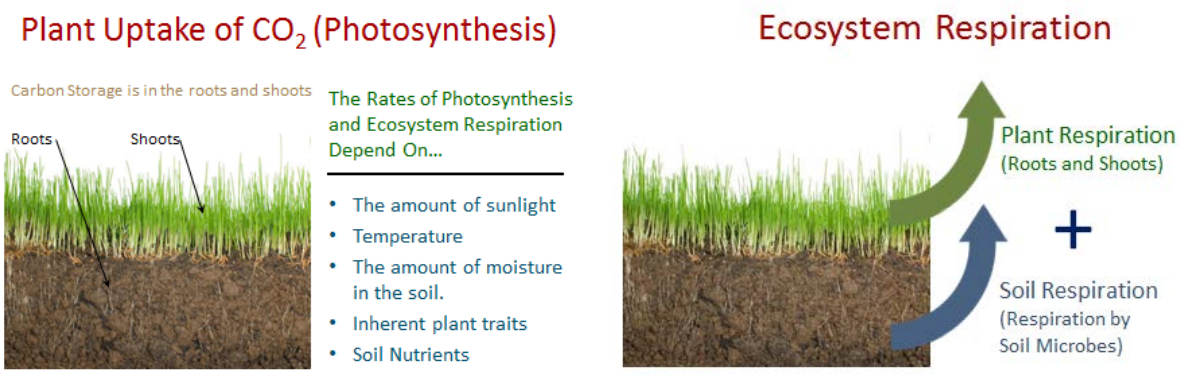
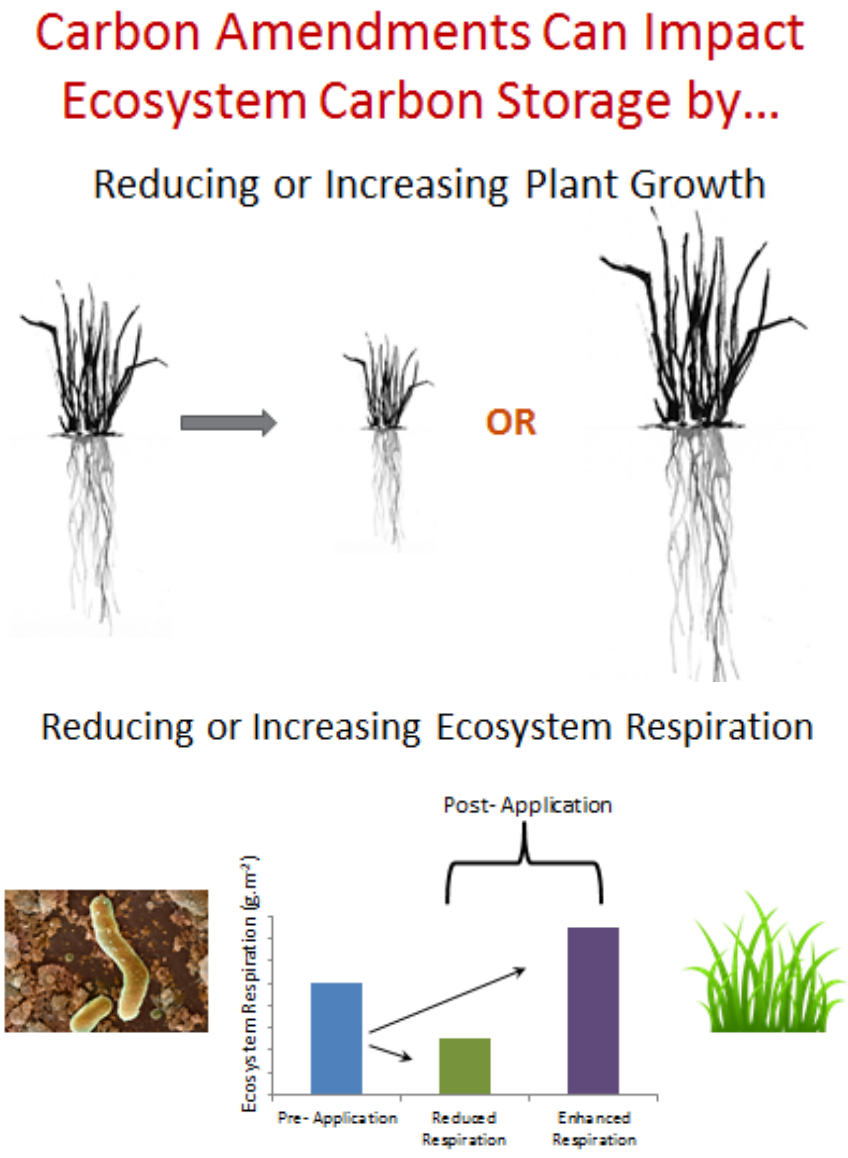


Figure 3: Carbon inputs and outputs to and from the ecosystem

Carbon storage is the net result of two primary processes, photosynthesis (i.e., carbon inputs to ecosystem storage from the atmosphere) and ecosystem respiration (i.e., carbon outputs to the atmosphere

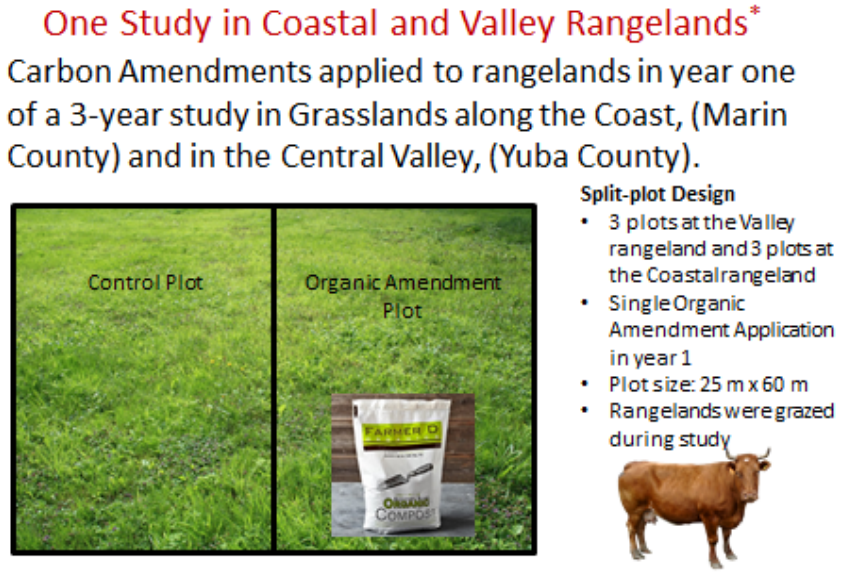
from the ecosystem). Both processes are governed by a range of factors, which include the amount of sunlight incident upon the surface, temperature, soil water content, the fraction of organic matter in the soil, the supply of nutrients to plants and microbes, and inherent plant and soil traits. If organic amendments are applied to the grassland surface, changes in these governing properties will likely result, leading to differences in the amount of ecosystem carbon storage via changes in photosynthesis (+/-) or ecosystem respiration (+/-). The balance between these carbon inputs and outputs from the ecosystem determines whether carbon is lost to the atmosphere or is added to the terrestrial storage pool.



UC Berkeley Research Study

In the counties of Marin (along the coast) and Yuba (in the Central Valley foothills), researchers from UC Berkeley performed an experiment in which they applied organic amendments to rangeland soils in a series of large (25 x 60 m) treatment and control plots. Specifically, the type

of organic amendment used in the study was compost produced in accordance with CalRecycle standards. Other types of organic amendments, if applied, may have led to different results than those achieved in this experiment.



The results of the study showed a difference between the two sites in the overall amount of ecosystem carbon storage. At both sites, comparisons between treatment and control plots revealed that the application of organic amendments in a single year led to enhanced growth rates in grassland plant species, when averaged over the next three years. Therefore, the organic amendments increased carbon capture by the ecosystem. Higher plant growth also meant additional fodder was available for grazing. However, organic amendments were also found to increase ecosystem respiration by plants and soil microbes averaged over three years, therefore resulting in higher carbon losses from the ecosystem to the atmosphere. Remarkably, organic amendments were also found to increase the carbon stored in soil organic matter quite dramatically at the Central Valley rangeland site, and to a lesser extent at the coastal site. Overall, this study found that organic amendments increased ecosystem storage of carbon at both the Central Valley and coastal rangeland sites, when averaged over the three years of the study.

For a complete greenhouse gas accounting, the UC Berkeley researchers also measured the impacts of the organic amendment treatment on the release of other greenhouse gases, particularly nitrous oxide (N_2O) and methane (CH_4). N_2O has a global warming potential equal to 265 times that of CO_2 in the atmosphere (i.e., one molecule of N_2O in the atmosphere traps 265 times the amount of heat as one molecule of CO_2, although CO_2 is far more abundant).[1] CH_4 has a global warming

[1] Intergovernmental Panel on Climate Change (2013). *Climate Change 2013: The Physical Science Basis.* Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker,T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M.

potential of 30 times that of CO_2.[2] In this experiment, release of both N_2O and CH_4 were found to be negligible, and therefore did not contribute to climate forcing.[3] However, different types of organic amendments could increase other greenhouse gas emissions, and will need to be accounted for to understand the full impact of organic amendment applications on global climate change.

Overall, in the UC Berkeley study, a single organic amendment application stored 192 (+/- 93) grams of carbon per square meter over three years, or approximately 0.8 metric tons of carbon per acre averaged across the coastal and Central Valley rangeland sites. If we were to apply organic amendments to all of Marin's pasture land (app. 154,000 acres), then 123,000 metric tons would be stored county-wide in a three- year period from a single organic amendment application. For comparison, the average passenger car emits 4.7 metric tons of CO_2, or 1.28 metric tons of carbon per year. Therefore, the amount of carbon drawn from the atmosphere into terrestrial storage in Marin County rangelands over three years would be equivalent to removing 96,250 cars, or 32,834 cars per year. Depending on how long the carbon storage effect of adding organic amendments lasts, and how frequently the amendments are applied, this technology could add up to a meaningful transfer of carbon from the atmosphere to terrestrial storage.

Benefits of Organic Soil Amendments

The emission of CO_2 and other greenhouse gases, (e.g., methane and nitrous oxide) through the burning of fossil fuels is causing global climate change, which directly impacts habitats and the human environment in Coastal California and globally. Impacts relevant to coastal processes include sea level rise, ocean acidification, shifts in the distribution of marine and terrestrial species, species loss, changes in the amount and timing of precipitation and sediment delivery to the coastal zone, impacts to agricultural production, and many others. Although the impacts of global climate change are already being realized, some potential impacts of climate change can be averted through efforts to reduce the release of greenhouse gases to the atmosphere, and also to draw carbon out of the atmosphere by increasing carbon sequestration in soils and plant biomass. Collectively, such actions can further mitigate impacts to the coastal environment.

Although small-scale, the results of the study discussed above indicate that the application of organic amendments to rangeland soils is a potentially promising tool for land managers interested in coastal ecosystem protection. Because of the link between climate change and coastal impacts, such measures can both contribute toward climate change mitigation, and reduce impacts to the built environment and natural ecosystems protected by the Coastal Act. Moreover, this research is in the early stages. Continued research on the climate benefits of organic amendment application to rangelands is ongoing, and expected to yield additional insights in the near-term. From a financial perspective, participation in California's carbon market can offset costs related to the implementation of an organic amendments program, and provide additional incentive for ranchers to participate.

Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. https://www.ipcc.ch/report/ar5/

[2] Ibid.

[3] Alternation of the climate, (*i.e.* increase in temperature or a shift in precipitation patterns).

Although most land-based activities are not currently accredited, they are increasingly becoming incorporated into the carbon offsets project portfolio.

In addition, the use of organic amendments has the potential to accrue benefits to ranchers and rangeland managers beyond climate change mitigation. Because organic amendments have high nutrient content, they can boost plant productivity, increasing the availability of fodder for cattle. By increasing the percentage of organic matter in soils, amendments can also increase the water holding capacity of the soil, which can in turn prolong the availability of water to plants, thereby increasing the length of the growing season and ameliorating the impacts of drought.

Opportunities for Advancing Beneficial Carbon Rangeland Amendments

Given the significant benefits of the application of organic amendments, in their consideration of development requiring a coastal development permit, the Coastal Commission, and local governments through their Local Coastal Programs, can consider the application of organic amendments as a means of mitigating carbon emissions, increasing soil productivity, and enhancing agricultural viability. Such mitigation must be considered on a case by case basis because mitigation must be implemented in a manner that is protective of other coastal resources, such as coastal waters and sensitive habitats, and therefore may not be feasible or appropriate in all locations.

The Coastal Act includes strong protections for agricultural land and agricultural viability, and requires soil productivity to be protected and enhanced. The Coastal Act also includes policies that result in reduced greenhouse gas emissions. For example, Section 30250 requires new development to be concentrated in existing developed areas, and Section 30253 requires new development to minimize energy consumption and vehicle miles traveled. These policies can reduce urban sprawl, protect habitat and reduce pollution. In addition, policies protecting the marine environment, open space, rangelands, and timberlands not only protect coastal habitats, but can also preserve the ecosystem services, including carbon sequestration, that those habitats provide. As a result, the Commission addresses climate change through its planning, regulatory, and educational activities.

Given the significant threats to coastal resources from the effects of global warming, many efforts have focused on identifying and encouraging strategies that will offset greenhouse gas emissions, and which will promote terrestrial carbon storage. Organic amendments to rangelands can be an important tool in carbon management. The associated benefits may include increased plant productivity, leading to increased fodder for livestock; reduced evaporative losses, alleviating the impacts of drought on rangelands; and enhanced soil fertility, perhaps increasing agricultural viability on marginal lands.

The use of organic amendments may also be advanced through the regulatory process. For example, it may be appropriate to require project mitigation for a development approved through a coastal development permit in which soil amendments could be used to reduce or offset impacts to agricultural or other coastal resources.

In addition, there may be opportunities for advancing the use of soil amendments and carbon storage through the local planning process, as local governments integrate climate change strategies and sustainability practices (e.g., drought planning, waste stream reduction/reuse, and increased energy efficiency) into their Local Coastal Programs (LCPs). As LCPs are updated and amended to address agricultural viability and climate change mitigation, the Coastal Commission encourages local governments to consider long-term carbon sequestration strategies, including soil amendments.

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